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The biorefinery transition in the European pulp and paper industry – A three-phase Delphi study including a SWOT-AHP analysis

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ABSTRACT

Because it is a mature industry, the European pulp and paper industry (PPI) possesses strengths due to its infrastructure, technological know-how, and the availability of biomass. However, the declining trend in the wood-based products sales, coupled with an increasing amount of global attention focused on a bio-based and circular economy, sends a clear signal to the industry, indicating that it needs to transform its business model to increase its profitability while contributing to climate change mitigation. Integrating the biorefinery concept as a value creation business model seems to be the pathway that will reach these objectives. This study was carried out to empirically assess and prioritize factors that affect the diffusion and implementation of the biorefinery concept in the European PPI. For this purpose, a three-phase Delphi study, including a SWOT-Analytic Hierarchy Process (AHP), was conducted. During the course of this study, the opinions of experts from industry and academia were gathered using both qualitative and quantitative methods. The findings reveal that the political dimension has a significant influence on the ability of individuals to tackle the economic barriers while reinforcing the environmental and social benefits in the macro-environment. At the industry level, the availability of biomass appears to be a strength of the PPI, while the knowledge gap regarding technology and the market represents a crucial barrier for the biorefinery development. The human resources issue is indicated as an important premise behind the identified barriers on a strategic level. Finally, five potential strategies for the biorefinery development in the PPI were derived by logically combining the results of the SWOT-AHP decision-making.

1. Introduction

Despite the strength of its industrial structures, the European PPI has faced many challenges in recent years that have changed its competitiveness dramatically. Increased amounts of competition from low-income countries (e.g. Brazil and Indonesia), the growing use of digital media, and the resulting declining demand for printing paper, as well as the environmental policy of the European Union (e.g. climate strategies for 2020, 2030 and 2050[1]) have led to declining growth and profitability in recent years (Näyhä and Pesonen, 2012; Hetemäki and Hurmekoski, 2014; Näyhä et al., 2015; Toppinen et al., 2017). For instance, the number of companies and mills in Europe decreased by > 30% between 2000 and 2017. The number of employees has also declined by 37% since 2000 (CEPI, 2018). Pätäri (2010) investigated this decreasing trend in the European PPI, stating that the industry has reached its maximum potential with its traditional business model and suggested shifting towards new business models that focus on the production of high value-added products along with traditional ones.

A promising approach that can be taken to encourage this shift is the implementation of forest biorefineries into traditional pulp and paper mills (OECD, 2009; Näyhä, 2012; Hansen and Coenen, 2017). The idea has been proposed as the most suitable configuration to take full advantage of the existing resources and increase the overall revenue streams and profitability (Chambost et al., 2008; Huang et al., 2008; Pätäri, 2010).

The biorefinery transition in the PPI has been discussed in the literature for several years (see e.g. Janssen and Stuart, 2010; Pätäri, 2010; Hämäläinen et al., 2011; Näyhä et al., 2014; Stern et al., 2015; McGuire et al., 2017). However, transforming the traditional business model of the PPI into a value-added one through the production of bio-

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[1] https://ec.europa.eu/clima/policies/strategies_en

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based products is still challenging, as processes need to be carried out to tailor the biorefinery plant and systems to optimize available functionalities (Langeveld et al., 2010). Moreover, such business model transformation does not end at the company boundaries. It implies a transformation of the whole PPI towards bioeconomy (Antikainen and Valkokari, 2016; Priefer et al., 2017).

The challenges that are associated with the biorefinery transition have also been reflected by its slow progress in recent years (Giurca and Späth, 2017; Hellsmark et al., 2016; Höher et al., 2016; Palgan and McCormick, 2016; Bauer et al., 2017). Hence, a deeper understanding of factors that influence the biorefinery transition in the PPI has to be gained to attain diffusion and development.

The aim of this study was to assess these influencing factors for the biorefinery transition in the European PPI empirically and prioritize them. The Delphi technique and SWOT-AHP methods were adopted. As the source of primary data, the opinions from biorefinery experts from the European PPI and academia were sought.

Previous studies have focused on the PPI more generally (e.g. Pätäri et al., 2016) or had a specific regional focus (e.g. Janssen and Stuart, 2010; Hämäläinen et al., 2011; Näyhä, 2012; Näyhä and Pesonen, 2012; Hellsmark et al., 2016; Giurca and Späth, 2017). Toppinen et al. (2017) also used a Delphi-approach to assess the current structure of the PPI and its potential for transformation and value creation in the year 2030. Our study distinguishes itself from the previous work by placing a specific focus on factors that affect the diffusion and development of forest biorefineries in the PPI and by using, for the first time in this context, a multiple-criteria decision-making method to weight the identified factors. By doing so, we addressed a research gap with regard to scientific studies that focus specifically on determinants for the success of the biorefinery transition in the PPI (Toppinen et al., 2017).

The remainder of this paper is structured as follows. In the next section, the theoretical foundation is provided, and drivers and barriers for the biorefinery transition in the European PPI derived from the literature are listed. In Section 3, the research process and methods used are described. In Section 4, the results of the Delphi study and the SWOT-AHP are presented. The results and limitations of the study are discussed in Section 5, and five potential SWOT strategies are provided. A conclusion to the study is given in Section 5.2 and directions for further research are provided.

2. Theoretical background

2.1. From pulp and paper to forest biorefineries

The PPI is based on a complex system with a diversity of products, raw materials, product qualities, distribution channels, and end uses. With regard to products, the PPI is basically a producer of pulp, paper, and other cellulose-based products. Most of these are typically intermediate products that are subsequently used as inputs for downstream value-added products, whereas certain other products are generally distributed to end consumers without further conversion, such as tissue and office paper (Hetemäki et al., 2013). The European PPI has a high export rate of 21% (CEPI, 2018).

Aside from its major contribution to the economy, the PPI can also be considered as a capital-intensive industry with regard to its economic industry structure and, furthermore, it is characterized by long-term planning (i.e. much longer than 30 years) for investment (Berends and Romme, 2001; Carlsson et al., 2009). Moreover, the technological know-how (Pätäri, 2010), economies of scale as a business strategy, and established sourcing systems for biomass as raw materials indicate this.

Bioeconomy can be understood as an economic system in which renewable biological resources are used for the production of materials, chemicals, and energy and, thus, substitutes for fossil resources (McCormick and Kautto, 2013; Hausknost et al., 2017). The use of these resources also enables a reduction of solid waste and, therefore, closure of material loops. Thereby, a positive environmental impact can be achieved (Bezama, 2015; Antikainen and Valkokari, 2016; Kraaijenhagen et al., 2016; Priefer et al., 2017). A key enabling factor for the transition to a bioeconomy is the development and diffusion of biorefinery systems (OECD, 2009; Hansen and Coenen, 2017). A biorefinery can be considered to be a relatively complex system. The biorefinery includes processes that convert different types of organic raw materials, utilize various types of conversion technologies, and finally produce a variety of biological products (Näyhä et al., 2014). In general, a biorefinery is a facility analogous to the petroleum refinery, which integrates sustainable biomass conversion processes and technologies to produce energy, fuel, or a broad spectrum of biobased-products (e.g. food, feed, materials, chemicals) (Mohan et al., 2016).

Experts have agreed for several years that the implementation of forest biorefineries has an enormous potential for the PPI and can bring numerous technological, environmental, economic, and social benefits, such as the following:

- Technological potential: Optimize existing value chains in order to generate additional value (Näyhä et al., 2014; Giurca and Späth, 2017).
- Environmental potential: Use the entire potential of raw materials in order to reduce waste, close material loops, and increase material efficiency (Näyhä et al., 2014; Oliveira and Navia, 2017). Replace materials based on fossil resources (Brodin et al., 2017).
- Economic potential: Enhance profitability by a more diversified product portfolio and, thereby, new customers in new markets (Janssen and Stuart, 2010; Höher et al., 2016; Hansen and Coenen, 2017).
- Social potential: Create new jobs and, thereby, contribute to the revitalization of rural areas, where the PPI mills are often located (Priefer et al., 2017).

2.2. Driving factors and barriers for forest biorefineries

To gain an overview of the forces that drive or hinder forest biorefinery implementation within the business activities of PPI, a literature review was conducted which also represents the basis for this study. The compiled set of prominent driving forces that are discussed in the literature are found in Table 1. These forces represent the entire value chain, starting from the raw material right through to the final customer. In addition, different stakeholders (e.g. government, financial sector) and other requirements (e.g. sustainability, innovation, collaboration) were recognized.

As shown in Table 2, barriers regarding the successful forest biorefinery transition could be identified from the literature as well. The barriers partially overlap with the previously shown driving forces, as driving forces could also create negative influences that hinder the successful development of forest biorefinery in PPI.

Based on the literature review summarized in Table 1 and Table 2, we can see that the implementation of forest biorefineries might be affected by a large number of forces. Some of these (collaboration, market, financing, legislation, raw materials) can either promote or inhibit the implementation. In summary, this set of driving and hindering factors served as starting point for the Delphi study.

3. Methods

The Delphi method is a forecasting technique, which entails the collection and compilation of knowledge from a selected group of experts (Dalkey and Helmer, 1962; Hsu and Sandford, 2007). It fosters the exploration of complex problems, especially in cases where historical data are lacking, there is insufficient knowledge, or a lack of agreement within the studied field (Okoli and Pawlowski, 2004). The Delphi method was applied to arrive at a reliable consensus of opinion by means of a repetitive assessment process with controlled opinion

Table 1
Driving factors for forest biorefinery implementation in PPI.

Driving factor	Description	Source
Collaboration	Collaboration between relevant actors in forest biorefinery value chains, cross-sectorial partnerships, but also collaborations with research institutes or universities.	Näyhä, 2012; Näyhä and Pesonen, 2012; Bajpai, 2013; Hellsmark et al., 2016; Giurca and Späth, 2017; Toppinen et al., 2017
Customer / market	Reaction to the chance of customer preferences to ensure short-term profitability and increasing its market value. Reaching new customer segments. Reaction on declining prices of traditional wood-based products.	Ragauskas et al., 2006; Kurka and Menrad, 2009; Menrad et al., 2012; Janssen and Stuart, 2010; Pätäri et al., 2011; Näyhä, 2012; Näyhä and Pesonen, 2012; Bajpai, 2013; Hetemäki et al., 2013; Pätäri et al., 2016; Giurca and Späth, 2017; Toppinen et al., 2017
Financing (public and private)	Financial support from government as well as availability of private financing.	Janssen and Stuart, 2010; Näyhä, 2012; Näyhä and Pesonen, 2012; Hellsmark et al., 2016
Innovation Management	New diversified innovative products and applications to serve customer needs better. Comprehensive R&D infrastructure, e.g. for demonstration and pilot plants.	Janssen and Stuart, 2010; Pätäri et al., 2011; Näyhä, 2012; Näyhä and Pesonen, 2012; Hellsmark et al., 2016; Pätäri et al., 2016; Toppinen et al., 2017
Legislation and (environmental) policies	Important macro-environment factors, particularly for their roles in providing stable framework for biorefinery implementation (e.g. taxation, land use, climate change). Support of current technology.	Ragauskas et al., 2006; Menrad et al., 2012; Peck et al., 2012; Janssen and Stuart, 2010; Näyhä, 2012; Näyhä and Pesonen, 2012; Giurca and Späth, 2017
Raw material	Future access to (sustainable) raw materials, in a sufficient quantity and quality as well at a competitive price. Decreasing dependence on fossil feedstock.	Kurka and Menrad, 2009; Menrad et al., 2012; Söderholm and Lundmark, 2009; Janssen and Stuart, 2010; Hämäläinen et al., 2011; Pätäri et al., 2011; Näyhä, 2012; Näyhä and Pesonen, 2012; Keijsers et al., 2013; Giurca and Späth, 2017
Sustainability	Bio-based economy with increased energy and material efficiency, and a decreasing ecological damage. To reach consumer segments with higher environmental awareness.	Chertow, 2004; Kurka and Menrad, 2009; Hämäläinen et al., 2011; Näyhä, 2012; Näyhä and Pesonen, 2012; Hetemäki et al., 2013; Pätäri et al., 2016; Toppinen et al., 2017

feedback (Landeta, 2006). As a formal consensus methodology, the Delphi method provides structured circumstances that *"[…] can generate a closer approximation of the objective truth than would be achieved through conventional, less formal, and pooling of expert opinion"* (Balasubramanian and Agarwal, 2012). The method is particularly useful in that it allows researchers to solve interdisciplinary research problems, where the opinions of experts are heterogeneous (Stern et al., 2012; Sutterlüty et al., 2016; Huber et al., 2018). Therefore, we considered the Delphi technique as a suitable method that would enable us to capture the inherent complexity within the field.

The Delphi method has four key characteristics that include anonymity, iteration, controlled feedback, and added statistics from a group of answers (Näyhä, 2012). Anonymity was applied to both the participants and their answers. Thus, social pressure and potential negative influence in the individual answers could be avoided (ibid). Moreover, the method was conducted iteratively to allow the participants to re-evaluate their responses in light of the result of the previous Delphi phase. In general, the Delphi method uses a variance of phases ranging from two to seven rounds (Somerville, 2007). In this study, after completing one Delphi phase, the iterative feedback was given to the participants as a simple descriptive summary, informing them of the opinions of their anonymous colleagues.

Aiming to identify all influencing factors of the forest biorefinery development in the PPI, it was necessary to carry out an in-depth discussion on certain important factors. Therefore, in a total of three Delphi phases, we used a combination of qualitative, semi-quantitative, and quantitative approaches to reach the goal of the study (see Fig. 1).

After determining the number of phases, the next critical step of selecting the experts was taken, although there is no defined guideline for determining the number of participants and their levels of expertise (Rikkonen and Tapio, 2009). While Clayton (1997) indicated that fifteen to thirty experts with homogenous expertise backgrounds or five to ten experts with heterogeneous backgrounds should be involved in a Delphi process, Adler and Ziglio (1996) argued that for a homogenous expertise background, ten to fifteen experts would be considered as an appropriate number of participants. In this study, the Knowledge Resource Nomination Worksheet (KRNW) was used as a guideline for the selection of participants. The KRNW was first developed by Delbecq

Table 2
Barrier factors for forest biorefinery implementation in PPI.

Barrier factor	Description	Source
Collaboration	Identification of partners may be critical to success, however, it is difficult to establish at this early stage.	Chambost et al., 2008; Janssen et al., 2008; Menrad et al., 2012; Söderholm and Lundmark, 2009; Janssen and Stuart, 2010; Hämäläinen et al., 2011; Näyhä, 2012; Hellsmark et al., 2016; Giurca and Späth, 2017; Hansen and Coenen, 2017
Market	Competition from other regions or over raw materials with other industries.	Hellsmark et al., 2016; Pätäri et al., 2016; Giurca and Späth, 2017
Financing (public and private)	Insufficient public and private financing. The marginal financial performance favors short-term decision and leads to avoidance of investment (see also risk-averse culture).	Menrad et al., 2012; Janssen and Stuart, 2010; Hämäläinen et al., 2011; Näyhä, 2012; Hansen and Coenen, 2017
Legislation and (environmental) policies	Can act as both drivers and barriers of biorefinery development. Especially increasing environmental regulation.	Menrad et al., 2012; Peck et al., 2012; Janssen and Stuart, 2010; Hämäläinen et al., 2011; Näyhä, 2012; CEPI, 2013; Pätäri et al., 2016; Giurca and Späth, 2017
Raw material	The demand of forest biorefineries cannot be satisfied with wood-based biomass (in terms of price and quantity).	Van Heiningen, 2006; Menrad et al., 2012; Söderholm and Lundmark, 2009; Hämäläinen et al., 2011; Näyhä, 2012; Hellsmark et al., 2016; Pätäri et al., 2016; Giurca and Späth, 2017
Risk-averse culture	Avoidance of technology or investment risks.	Janssen and Stuart, 2010; Näyhä and Pesonen, 2012; CEPI, 2013; Höher et al., 2016; Pätäri et al., 2016; Toppinen et al., 2017
R&D expertise	R&D competences are not sufficient to enable biorefinery implementation; R&D competition from abroad.	Hämäläinen et al., 2011; Näyhä, 2012; Giurca and Späth, 2017
Technology	Higher technology risk by implementing inefficient early-generation technologies.	Chambost and Stuart, 2007; Janssen and Stuart, 2010; Giurca and Späth, 2017

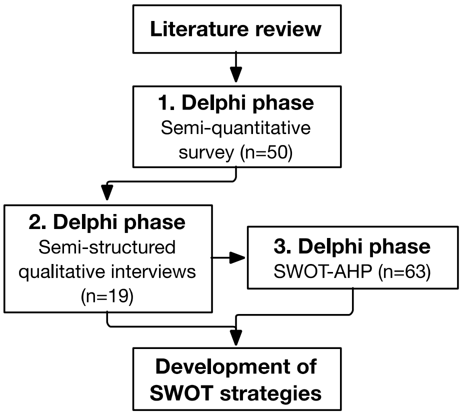

Fig. 1. Overview of the research process.

Table 3
Composition of the expert panel that was invited to participate in the Delphi study.

Category	Number of experts			
	Europe	North America	Asia	Total
Academia	80	12	3	96
Industry	59	0	0	59
NGOs, NPOs, and associations	28	0	0	28
Governmental institutions	1	5	0	6
Total	**168**	**17**	**3**	**188**

The bold line shows the sum of experts according to their geographical location.

et al. (2007) with the purpose of providing a guideline for how to select experts for a group technique study. The KRNW involves the following five steps: (1) Preparation of the KRNW; (2) population of the KRNW; (3) nomination of additional experts; (4) ranking of experts; and (5) invitation of experts. In the first step, four categories of experts were selected for this study: 1) academia, 2) industry, 3) NGOs, NPOs, and associations, and 4) governmental institutions. In the second step, the category academia was populated with expert's names based on a search for the keyword “biorefinery” in Google Scholar. Experts in the categories 2) - 4) were selected from biorefinery-related research consortiums in the European Union 7th Framework Program (FP 7), based on a search conducted in the CORDIS database. Step three was omitted, because we considered the size of the expert panel to be sufficient. The ranking of experts in step four was based on the number of publications and citations for the category academia. In the categories 2–4 from each institution involved in a relevant research project, the primary contact person was selected. In step five, a total of 188 experts were personally invited via e-mail, and the e-mail included a brief explanation of the background, the goals, and the expected outcomes of the study. In Table 3, the composition of the expert panel according to their geographical location is summarized.

As illustrated in Fig. 1, the semi-quantitative approach was carried out during the first phase. For this purpose, an online questionnaire was created which contained different types of questions (e.g. multiple-choice questions, Likert questions, and open questions). Therefore, the experts had the opportunity to discuss their opinions and ideas on the topics in a flexible manner. As we had been able to derive a set of general driving and barrier factors from the literature, this approach appeared reasonable. It allowed us to assess previously identified factors in our specific context quantitatively and, at the same time, obtain more specific additional factors in a qualitative manner. The obtained results were the basis of a focus placed on the important factors for the subsequent, second Delphi phase of semi-structured interviews. In these interviews, the experts provided detailed explanations for the factors

Table 4
Summary of the Delphi method processes in the study.

Phase	Main goals	Approach	Data collection	Invited Participants
First phase	Identify relevant factors affecting the forest biorefinery development in the PPI.	Semi-quantitative	Online-based survey	188
Second phase	Evaluate the result from the first round and develop in-depth discussions on the important factors for the biorefinery development.	Qualitative	Personal interview	Voluntarily from the first phase participants
Third phase	Prioritize SWOT-factors for the biorefinery transition in the PPI.	Quantitative	Online-based survey	188

from their varying perspectives. In the third phase of our Delphi-study, we applied a combination of a Strength, Weaknesses, Opportunities, and Threats (SWOT) analysis and an AHP to quantify and weight the factors. By adopting this multi-criteria decision-making method, our study distinguishes itself from other, comparable recent publications (see Toppinen et al. (2017) for a summary), which primarily followed qualitative approaches.

The AHP was first combined with SWOT analysis by Kurttila et al. (2000) to advance the decision-making capabilities of the SWOT analysis, which had formerly been mainly qualitative. Since then, SWOT-AHP has proven effective in various contexts but has, to the best of our knowledge, not previously been applied in PPI or biorefinery-related research.

To set a basis for the SWOT-AHP analysis, we categorized the drivers and barriers from the first two stages of the Delphi study into SWOT groups and then merged and condensed them to three SWOT factors per group. In the following, an online-questionnaire (Limesurvey) was composed, which was, after a pre-test had been run, distributed to the initial panel of 188 experts (Table 4) between December 2016 and January 2017. The questionnaire entailed a pair-wise comparison of the individual SWOT factors (i.e., Sa with Sb, Sa, with Sc, Sb with Sc, etc.) and of the four SWOT groups (i.e. S with W, S with O, S with T, etc.). For the pair-wise comparison, a nine-point scale was used. The scale deliberately consisted only of odd numbers and ranged from 9/1 (e.g. factor Sa is much more important than factor Sb), over 1/1 (e.g. factors Sa and Sb are equally important) to 1/9 (e.g. factor Sb is much more important than factor Sa) (Saaty, 1986). We then used the geometric mean (Forman and Peniwati, 1998; Saaty, 2008) of the 63 individual expert judgements to calculate the relative priorities p $(0 < p < 1, \sum_{i=1}^{n} pi = 1)$ of n SWOT factors per group following the eigenvalue method (Saaty, 1980). The local priority $lp(f)$ represents the relative importance of a SWOT factor in its respective SWOT group (e.g. the relative importance of Sa, Sb and Sc in the group of Strengths). The group priority $p(g)$ represents the relative importance of a SWOT group (e.g. the relative importance of the group Strengths compared to Weaknesses, Opportunities, and Threats). By multiplying $lp(f)$ with $p(g)$, the global priority of a SWOT factor $gp(f)$ could be calculated. This priority value represents the relative importance of a SWOT factor in relation to all other SWOT factors. Finally, we computed the collective consistency ratios (CR) of the factor and group comparison matrices to test for inconsistencies that would be indicated by a $CR > 0.1$ (Saaty, 1986). As pointed out by Ossadnik et al. (2016), despite possible inconsistent individual judgements, the calculation of the geometric mean of individual judgements can increase the consistency of the group judgement and, thus, also the quality of the decision.

To integrate the qualitative results of the first two Delphi stages with the quantitative prioritization with the SWOT-AHP during the third stage, we searched for logical combinations between the SWOT factors to derive potential strategies from our study following the approach cited by Rauch (2006).

In Table 4, the phases of the Delphi method included in this study are summarized.

4. Results

Each phase of the study involved a different number of experts in the panel. The online-based survey conducted during the first phase allowed us to successfully gather the perspectives of fifty experts, 60% of whom were from academia, followed by industry (24%), and NGOs, NPOs, and associations (12%). The interviews during the second phase were conducted with nineteen experts, who were more equally distributed between groups (39% from academia and nearly the same percentage from the industry). During the third phase, the expert panel from the first phase was contacted again, and feedback was obtained from 63 experts. The distribution of the experts was again equally distributed, with around 46% from academia and 44% from industry. In Table 5, a detailed composition of the expert panel during all three phases of the study is presented.

Table 5
Composition of expert panels.

Category	Number of experts		
	First phase	Second phase	Third phase
Academia	30	8	29
Industry	12	7	28
NGOs, NPOs, and associations	6	1	6
Governmental institutions	2	3	0
Total	**50**	**19**	**63**

The bold line shows the sum of experts within the respective Delphi phase.

Furthermore, the panels consisted of experts in multiple fields, which enhanced the multidisciplinary nature of the research approach. The majority of the experts displayed expertise in bio-based products, followed by expertise on biomass, economy, and technology.

In the following sub-section, the results from the survey are described, and an in-depth discussion of the selected topics is presented.

4.1. Results Delphi phase 1 and 2

4.1.1. Driving factors

During the first Delphi phase, the importance of driving factors that were derived from the literature (see Table 1) was assessed using a five-point Likert scale. The list of factors that was derived from the literature was extended after a pre-test was conducted with members of a biorefinery research consortium. As shown in the second column of Table 6, the participants evaluated five of the listed factors as important (grouped median > 4), while three of the listed factors were evaluated as neutral (grouped median 3–4). The three most important factors were the *"increasing demand for sustainable material"* (grouped median - gm = 4.47), followed by the *"availability of technology"* (gm = 4.38) and the availability of raw materials" (gm = 4.35).

To increase the comprehensiveness of our results, the experts were also encouraged to name any other factors that they considered to be important drivers for the biorefinery development in the PPI. In Table 7, the additional, mentioned factors categorized as *economy*, *ecology*, *social*, *policy*, and *business model* are presented.

Once the second Delphi phase had been carried out, a consensus among experts was obtained, indicating the conformity of their views with the survey results from the first phase. A summary of the statements of the experts can be found in the third column of Table 6.

4.1.2. Barrier factors

The second column of Table 9 presents the survey results for the barrier factors, which were derived and assessed in the same way as the driving factors. In contrast to the results for the drivers, only two barrier factors were considered as important (gm > 4), namely, the factors *"price competition with fossil feedstock"* and *"high investment costs."* Five factors were considered as neutral (gm between 3 and 4), and one factor, *"limited qualified human resources"* was considered as not important (gm between 2 and 3).

The expert panel, through the open-ended section, listed a total of eight additional factors that they consider to be hurdles to the forest biorefinery development in the PPI. The factors were grouped into the categories *economy*, *ecology*, *policy*, *industry attitude*, and *business model* (see Table 8). As only a maximum of two out of fifty experts mentioned the same additional driving or barrier factor, the initial selection of factors proved to be both valid and diverse. Nevertheless, the additional factors were also discussed with the experts during the second Delphi phase.

The results of the second Delphi phase demonstrate that, in general, the experts found the survey results from the first phase to be mostly in

Table 6
Result of the driving factors issued during the first and second Delphi phases.

Driving factors	1. Delphi phase						2. Delphi phase
	N[a]	Min[b]	Max[b]	Grouped median[b]	Mean value[b]	Standard deviation	
Increasing demand for sustainable material	49	1	5	4.47	4.37	0.834	• major driving factor of market formation for bio-based products • increasing awareness towards sustainability is expected • transition from fossil-based materials to bio-based products • demand for bio-based products based on sustainable materials will gradually grow and can lead to increasing profits for PPI
Availability of technology	49	3	5	4.38	4.35	0.631	• existing technology is evaluated to be underdeveloped for processing biomass into qualitative bio-based products • interrelated with driving factors R&D activities and knowledge transfer
Availability of raw materials	49	1	5	4.35	4.20	0.957	• important driver • available volume of biomass is a critical factor, especially aiming completely replacing the fossil-based products • price of biomass is important for competitive bio-based products
Marketing activities	50	2	5	4.23	4.10	0.931	• building consumer awareness on bio-based products • due to higher prices of bio-based products, marketing activities play important roles for promoting their sustainable values • in combination with public education
R&D activities	49	3	5	4.18	4.14	0.707	• crucial for developing forest biorefinery technology into a mature stage • provides scientific information regarding biomass as raw materials for bio-based products • many improvements through extensive R&D but often still on lab scale
Knowledge transfer	50	2	5	3.88	3.78	0.954	• knowledge transfer from theory to practice is unsatisfactory • need to establish partnerships, particularly between academia and industry
Financial support from government	50	1	5	3.72	3.68	0.935	• long-term government funding needed to support the R&D activities • lower investment risk • penalties for industries when the business activities contribute to environmental degradation, i.e. production of fossil-based products
Availability of skilled workforce	49	1	5	3.54	3.53	0.868	• neutral driving force • sufficient technical know-how within PPI at the moment • needs to engage more skillful workforce in the downstream part of the value chain

aNumber of experts answering the question in the 1st Delphi phase.
[b] Likert-type question using five-point scale, where: 1 = not important at all; 2 = not important; 3 = neutral; 4 = important; 5 = very important.

Table 7
Additional drivers.

Category	Factors
Economy	Profitability (2)
	Demand for bio-based products with right price and performance (2)
	Global trade of biomass (1)
Ecology	Sustainability in the production of raw material (1)
Social	Public awareness (2)
	Rural economy (1)
Policy	Supportive and stable policy (1)
	Consistency of policy environment (1)
Business model	Integration with the concept of circular economy (1)
	Cooperation with chemical industry (1)

Note: () = number of mentions.

Table 8
Additional barriers.

Category	Factor
Economy	Access to risk capital (1)
	Affordable price for products (1)
Ecology	Targeting and monitoring sustainability of biorefinery (1)
	Lack of biomass quality standard and assessments (1)
Policy	Difference between national policies (1)
Industry attitude	Conservatism and resistance of evolving within the PPI (2)
Business model	Enormous number of new products (1)
	Lack of specialized industry (1)

Note () = number of experts contributing into the online-based survey.

accordance with their views. However, the varied quality of raw materials and inadequate markets were not acknowledged during the second phase, indicating its low relevance as a barrier. Some other dissenting views also emerged during the in-depth discussions about a few of barrier factors. An overview of the expert statements is given in column three of Table 9.

4.2. Results of Delphi phase 3 - SWOT-AHP

As outlined in Section 3, the SWOT-AHP questionnaire was sent to the initial panel of 188 experts. A total of 63 experts provided answers, which were distributed as follows: 29 scientists, 28 industry, 6 NGOs, associations and governmental institutions (see Table 5).

Table 10 and Fig. 2 illustrate the results per SWOT-factor and per group. The group with the highest priority was the *strengths* (normalized group priority p(g) of 0.29; illustrated by the black dots in Fig. 2, followed by *threats* (0.26), Opportunities (0.23), and Weaknesses (0.22). Table 10 also provides the local priorities lp(f) and ranks of the individual factors per group as well as their global priorities gp(f) and ranks among all factors. The local priorities and ranks represent the importance of the factors within their respective groups, and the global priorities and ranks represent the overall importance of a factor relative to the twelve factors. The Weakness-factor *"High investment and economic risk for biorefinery development"* was ranked first among all factors with a global priority *gp* of 0.116, followed by the Threat-factor *"Price competition with fossil feedstock on the sales market"* (*gp* = 0.105) and the Strength-factor *"High efficiency in biomass utilization due to optimized cogeneration of products and bioenergy"* (*gp* = 0.102). the remaining two strength factors *"Improved competitiveness due to mid to long-term technological progress"* and *"Reduced market risks due to broadened product portfolio"* were ranked fourth and fifth, followed by the first opportunity-factor *"Increased public awareness and demand for sustainable industries and products."*

5. Discussion

The results of the SWOT-AHP may be interpreted as an optimistic expert appraisal of the PPI's capability to achieve the biorefinery transition, as its "Strengths" received the highest group priority. However, two aspects of the results counteract this optimistic view. First, the experts considered the external "Threats" as being more important than the "Opportunities" and, second, when comparing all factors, the Weakness-factor *"High investment and economic risk for biorefinery development"* and the Threat-factor *"Price competition with fossil feedstock on the sales market"* were ranked as more important than the first Strength-factor. The results of the SWOT-AHP reflect the findings of the preceding Delphi phases: Already in the quantitative survey conducted during the first phase, the price competition of bio-based products with fossil feedstock (rank 1) as well as high investment that is needed for biorefinery development (rank 2) were classified as important barrier factors. These findings were also confirmed by experts during the second Delphi phase, during which the importance of the two factors were discussed together.

Overall, the SWOT-AHP-Delphi approach used in this study appears to have been a viable option to elaborate on drivers and barriers of the forest biorefinery transition within the European PPI. Nevertheless, some limitations of the findings should be noted. The quality of the results of any expert survey depends highly on the selection of the appropriate experts (Sutterlüty et al., 2016). Despite the fact that efforts were made to gather a large number of highly qualified experts for the panel, the results may have been biased by the sample selection and non-response bias in some way (Huber et al., 2018). However, the study is based on a relatively large sample and comparably high return rate.

A limitation of the SWOT-AHP method is that it does not account for interdependencies between the factors. It would have been possible to account for these, for instance, if an ANP had been used. This method, however, requires a higher number of pair-wise comparisons. ISM, could also be used to identify interdependencies, but it does not allow the factors to be weighted. Consequently, the SWOT-AHP method was used in the present paper, because it allowed us to keep the pair-wise comparisons at a manageable level and provided the basis for subsequently formulated strategies. Regarding these strategies, described in Section 5.1, we refrain from claiming their general validity, as context-specific factors need to be taken into consideration when studying particular cases of biorefinery implementations. Nevertheless, they provide directions for future research, which can be followed in more specific studies.

5.1. Evaluation of strategic options

In order to discuss strategies for the PPI that optimize the strengths and opportunities of the biorefinery implementation while minimizing its threats and weaknesses, the four SWOT areas can be logically combined with each other (Kohlöffel, 2000; Rauch, 2006). Strategies can be derived from the expert's opinions gathered in the three Delphi stages and, thus, the qualitative and quantitative results of our study can be integrated. The following four strategic areas cover most of our results and relate them to the existing literature (Table 11):

5.2. Marketing to address new customers (Sb/Oa/Oc)

According to the results of the Delphi study, the increasing demand for sustainable materials was perceived as a major driving factor of market formation for products from forest biorefineries. Although the consumers' awareness and acceptance of bio-based products has been rather low, especially since such products have similar properties as fossil-based products but higher prices (Vandermeulen et al., 2012; Giurca and Späth, 2017), experts of the Delphi study believed that the demand for bio-based products would gradually grow. The speed of this growth, however, could be predicted. With regard to consumers, price

Table 9
Result of the barrier factors issue from first and second Delphi phases.

Barrier factors	1. Delphi phase						2. Delphi phase
	N[a]	Min[b]	Max[b]	Grouped median[b]	Mean value[b]	Standard deviation	
Price competition with fossil feedstock	49	2	5	4.18	4.12	0.807	● interrelated with high investment costs and immature technology, which create causal effects between each other ● low price of fossil feedstock influences competitiveness of bio-based products
High investment costs	50	2	5	4.06	4.02	0.82	● strongest barrier ● high investments in traditional business model to avoid risks ● due to low competitiveness of bio-based products, low interest of investors to support biorefinery development
Immature technology	50	1	5	3.85	3.75	0.986	● major cause of the investment barrier ● lead to high production costs and, therefore, an incapability to carry on the forest biorefineries in an economically viable manner
Inadequate markets	50	1	5	3.75	3.68	1.019	● barrier not relevant during second Delphi phase
Varied quality of the raw materials	50	1	5	3.61	3.52	0.995	● barrier not relevant during second Delphi phase
Lack of cooperation	50	2	5	3.51	3.52	0.931	● barrier not relevant during second Delphi phase
Established regulations do not fit with new technologies	50	1	5	3.38	3.36	1.025	● regulatory risk due to fragmented and inconsistent policy and regulations leads to less favorable position of bio-based products ● current regulations do not include externalities of fossil products ● inadequate standardization, labelling, and certification system for bio-based products ● consistent methodology for quantification of sustainability values for bio-based products still missing
Limited qualified human resources	50	1	5	2.94	2.88	0.895	● existing human resources do not have capabilities to integrate forest biorefineries into PPI mills ● conservative way of thinking ● might be seen as an unattractive industry for younger generation to pursue career

[a] Number of experts answering the question.
[b] Likert-type question using five-point scale, where: 1 = not important at all; 2 = not important; 3 = neutral; 4 = important; 5 = very important.

Table 10
Results of the SWOT-AHP study.

SWOT Factors	CR	Group priority	Local priority (rank)		Global priority (rank)	
Strengths (internal)	0.010	0.29				
Sa: Improved competitiveness due to mid to long-term technological progress			0.34	(2)	0.098	(4)
Sb: Reduced market risks due to broadened product portfolio			0.31	(3)	0.090	(5)
Sc: High efficiency in biomass utilization due to optimized cogeneration of products and bioenergy			0.35	(1)	0.102	(3)
Weaknesses (internal)	0.001	0.22				
Wa: Short-term limitations in the availability of biorefinery technologies			0.24	(2)	0.053	(11)
Wb: High investment and economic risk for biorefinery development			0.53	(1)	0.116	(1)
Wc: Difficulties to ensure stable quality and applicability of biorefinery products			0.23	(3)	0.051	(12)
Opportunities (external)	0.000	0.23				
Oa: Increased prices of products based on fossil feedstocks			0.27	(3)	0.062	(10)
Ob: Increased supportive and stable policy for low-carbon economy			0.36	(2)	0.084	(7)
Oc: Increasing public awareness and demand for sustainable industries and products			0.37	(1)	0.086	(6)
Threats (external)	0.005	0.26				
Ta: Increasing price competition on the raw-material market due to limited biomass availability			0.28	(3)	0.073	(9)
Tb: Price competition with fossil feedstock on the sales market			0.41	(1)	0.105	(2)
Tc: Uncertainty on targeted products and markets			0.31	(2)	0.079	(8)

Note $N = 63$; CR = consistency ratio (< 0.1 = accepted consistency)

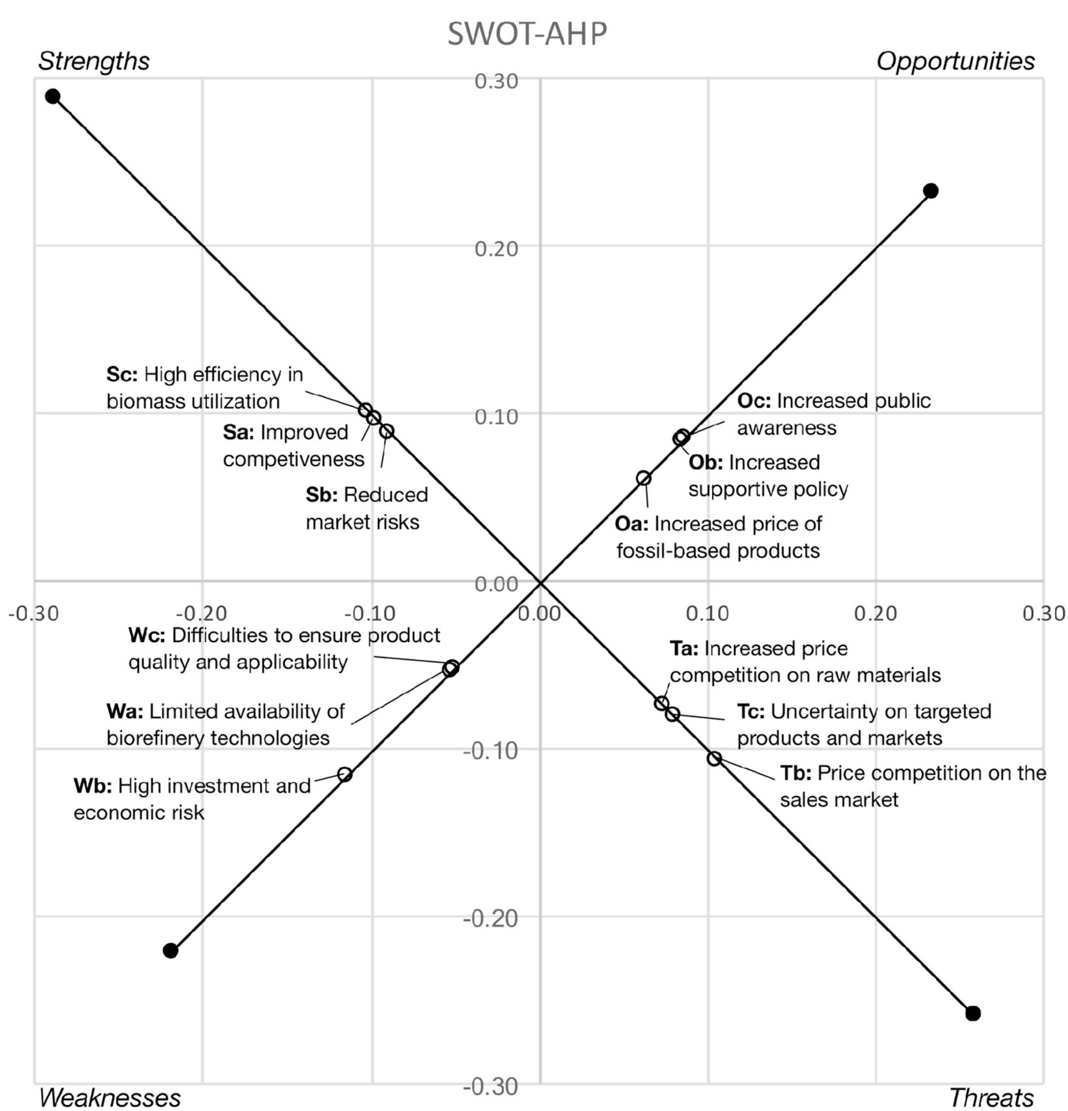

Fig. 2. Results of the SWOT-AHP study.
Note black dots = group priorities, white dots = global factor priorities

Table 11
SWOT strategy matrix.

	Strengths *(internal)*	Weaknesses *(internal)*
Opportunities *(external)*	Marketing to address new customers *(Sb/Oa/Oc)*	Policy support *(Wb/Ob)*
Threats *(external)*	Optimization of biomass *(Sc/Ta)* New value chains *(Sb/Tc)*	Research cooperation *(Wa/Wb/Wc/Tb)*

is always expected to be the first criteria for the consumers' purchase decisions rather than quality. Experts interviewed in our Delphi study, but also those interviewed by Giurca and Späth (2017), argued that marketing activities play important roles for promoting the sustainable values of bio-based products and, therefore, enable them to gain a competitive advantage. Nonetheless, the experts confirmed that marketing activities do not have to be prioritized at the present time but, instead, in the future, considering the fact that the bio-based products themselves have not yet reached the commercialization stage. Combining marketing activities with public education will arguably increase the consumer awareness on sustainability (Pätäri et al., 2016; Giurca and Späth, 2017), thus, increasing the demand for sustainable materials.

5.3. Optimization of biomass utilization (Sc/Ta)

The availability of raw materials was identified as a key factor for developing forest biorefinery within PPI by the experts interviewed in our Delphi study, and this view is reflected in the literature. The availability is interpreted in two different ways:

Firstly, in a quantitative way, meaning the available volume. It appears that raw material for forest biorefinery in form of wood biomass is available in relatively large quantities. However, this total quantity is limited by the ability of companies to collect, transport, and utilize this biomass. Therefore, the procurement and logistics of raw material were considered to be a key success factor for the PPI's transition to forest biorefineries (Pätäri, 2010; Näyhä and Pesonen, 2012). In addition, a large amount of raw material is already used for the production of bioenergy. Therefore, wood biomass can be seen as critical factor that significantly influences the available amount of raw materials for bio-based production. Despite this threat, the PPI is in good position as a well-organized procurement and logistics system for large quantities of wood biomass as raw material for forest biorefineries already exists (Pätäri et al., 2011).

Secondly, the availability of raw materials is interpreted in terms of price. It is argued that raw materials can be considered to be available if they have an affordable price. Due to the ongoing global interest in bio-based products as well as bio-based energy, the demand for biomass as raw material has been expected to increase (Janssen and Stuart, 2010; Pätäri et al., 2011; Stern et al., 2015; Hagemann et al., 2016; Pätäri et al., 2016; Giurca and Späth, 2017; Toppinen et al., 2017). A strength that counteracts the threat of increasing biomass prices is the increased resource efficiency of forest biorefineries (Stern et al., 2015). The integration of forest biorefineries in existing production plants allows the PPI to simultaneously produce their classical product portfolio and generate bio-based products and bio-energy (Chambost et al., 2008; Oliveira and Navia, 2017).

5.4. Research cooperation (Wa/Wb/Wc/Tb) and new value chains (Sb/Tc)

Experts interviewed during our Delphi study argued that the availability of the technology is an important driving factor that enhances forest biorefinery development in PPI (Hedeler et al., 2018). Experts argued that PPI representatives currently want to underline the perceived risks in investing in forest biorefineries. This risk-averse culture of PPI has been perceived as a barrier to the diffusion of forest biorefineries (Delphi study but also Janssen and Stuart, 2010; Näyhä and Pesonen, 2012; Toppinen et al., 2017).

Since the necessary resources are often not available in the PPI, cooperation with research institutes or universities is necessary in order to improve technology and increase quality (see also Pätäri et al., 2011). In the context of R&D, knowledge transfer was also cited as an important factor by the interviewed experts in our Delphi study. A few experts commented that, currently, the knowledge for developing forest biorefinery has reached a sufficient level, but the transfer from theory to the practice is still lagging behind.

According to the experts, an important factor that ultimately will determine the success or failure of forest biorefinery in PPI is the need to establish a new value chain. Therefore, it is essential to promote cooperation with new customers, such as members of the chemical industry (see also e.g. Giurca and Späth, 2017; Toppinen et al., 2017). For the PPI, this cooperation, regardless of the form of partnership or commercial relationship, is also crucial to obtain any relevant information for product development.

5.5. Policy support (Wb/Ob)

Political support can also make a valuable contribution to offsetting development risks. Our results are in line with those of many other studies, which have reached the conclusion that policies and their financial incentives play significant roles in biorefinery development (e.g. Janssen and Stuart, 2010; Stern et al., 2015; Giurca and Späth, 2017).

Governments can influence the price structure of the market through regulatory measures, such as greater taxation of fossil fuels, thus, giving bio-based products a competitive advantage. It has been observed that a regulatory risk exists due to the fragmented and inconsistent nature of current policies and regulations, which consequently place bio-based products in less favorable positions compared to fossil-based products. A comprehensive overview of options and measures of policy has been given by Hellsmark et al. (2016) and Giurca and Späth (2017).

6. Conclusion

The primary goal of this study was to empirically assess factors that are influencing the biorefinery transition in the European PPI. By effecting this transition, the PPI could capitalize on its capabilities of biomass utilization and expand its current product portfolio with new, high-value-added products. To gain a deeper understanding of the internal and external factors that are influencing this implementation, a three phase Delphi study and a SWOT-AHP were conducted.

In general, the study findings reveal the complexity of the forest biorefinery transition within the European PPI, given the relatively high number of relevant factors and small differences in the overall factor weighting. The slow progress observed regarding the biorefinery transition of the European PPI (Giurca and Späth, 2017; Hellsmark et al., 2016; Höher et al., 2016; Palgan and McCormick, 2016) can be interpreted as a consequence of the high costs and economic risks based on our results. Economic risk was also associated with the unfavorable price competition with fossil feedstocks. This association between the main weakness and the main threat may dominate over the highly ranked strengths. Moreover, the strengths identified in the study indicated that a rather slow, step-by-step transition would take place

while dominating opportunities are lacking.

From the policy-maker and researcher perspectives, our study pinpoints the need to address the question of appropriate investment costs and product price differences for biorefinery development.

In future studies, other multi-criteria decision-making methods such as ISM, TOPSIS, ANP, or DEMATEL can be used to elucidate the factors identified in this Delphi study in more detail. The general strategies formulated can also serve bases for studying specific cases of transforming pulp and paper plants into forest biorefineries.

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References

Adler, M., Ziglio, E., 1996. Gazing into the Oracle: The Delphi Method and Its Application to Social Policy and Public Health. Jessica Kingsley Publishers, London/Philadelphia.

Antikainen, M., Valkokari, K., 2016. A framework for sustainable circular business model innovation. Technol. Innov. Manag. Rev. 6, 5–12.

Bajpai, P., 2013. Biorefinery in the Pulp and Paper Industry, Biorefinery in the Pulp and Paper Industry. Academic Press, London/Oxford/Amsterdam/Waltham/San Diego.

Balasubramanian, R., Agarwal, D., 2012. Delphi technique - A review. Int. J. Public Heal. Dent. 3, 16–25.

Bauer, F., Coenen, L., Hansen, T., Mccormick, K., Palgan, Y.V., 2017. Technological innovation systems for biorefineries: a review of the literature. Biofuels Bioprod. Biorefin. 11, 534–548. https://doi.org/10.1002/bbb.1767.

Berends, P.A.J., Romme, A.G.L., 2001. Cyclicality of capital-intensive industries: a system dynamics simulation study of the paper industry. Omega 29, 543–552. https://doi.org/10.1016/S0305-0483(01)00043-3.

Bezama, A., 2015. Let us discuss how cascading can help implement the circular economy and the bio-economy strategies. Waste Manag. Res. 34, 593–594. https://doi.org/10.1177/0734242X16657973.

Brodin, M., Vallejos, M., Tanase, M., Cristina, M., Chinga-carrasco, G., 2017. Lignocellulosics as sustainable resources for production of bioplastics e A review. J. Clean. Prod. 162, 646–664. https://doi.org/10.1016/j.jclepro.2017.05.209.

Carlsson, D., D'Amours, S., Martel, A., Rönnqvist, M., 2009. Supply Chain Planning Models in the Pulp and Paper Industry. INFOR Inf. Syst. Oper. Res. 47, 167–183. https://doi.org/10.3138/infor.47.3.167.

CEPI, 2013. Key Statistics 2012 - European Pulp & Paper Industry. Brussels.

CEPI, 2018. Key statistics 2017 - European Pulp & Paper Industry. Brussels.

Chambost, V., Stuart, P.R., 2007. Selecting the most appropriate products for the forest biorefinery. Ind. Biotechnol. 3, 112–119. https://doi.org/10.1089/ind.2007.3.112.

Chambost, B.V., Mcnutt, J., Stuart, P.R., 2008. Guided tour: Implementing the forest biorefinery (FBR) at existing pulp and paper mills. Pulp Pap. Canada 7, 1–9.

Chertow, M.R., 2004. Industrial Symbiosis. In: Cleveland, C.J. (Ed.), Encyclopedia of Energy. Elsvevier, New York, pp. 407–415.

Clayton, M.J., 1997. Delphi: a technique to harness expert opinion for critical decision-making tasks in education. Educ. Psychol. 17. https://doi.org/10.1080/0144341970170401.

Dalkey, N., Helmer, O., 1962. An Experimental Application of the Delphi Method to the Use of Experts.

Delbecq, A.L., Van de Ven, A.H., Gustafson, D.H., 2007. Group Techniques for Program Planning: a Guide to Nominal Group and Delphi Processes. Scott, Foresman, Michigan.

Forman, E., Peniwati, K., 1998. Aggregating individual judgments and priorities with the analytic hierarchy process. Eur. J. Oper. Res. 108, 165–169. https://doi.org/10.1016/S0377-2217(97)00244-0.

Giurca, A., Späth, P., 2017. A forest-based bioeconomy for Germany? Strengths, weaknesses and policy options for lignocellulosic biorefineries. J. Clean. Prod. 153, 51–62. https://doi.org/10.1016/j.jclepro.2017.03.156.

Hagemann, N., Gawel, E., Purkus, A., Pannicke, N., Hauck, J., 2016. Possible futures towards a wood-based bioeconomy: a scenario analysis for Germany. Sustainability 8. https://doi.org/10.3390/su8010098.

Hämäläinen, S., Näyhä, A., Pesonen, H., 2011. Forest biorefineries - A business opportunity for the Finnish forest cluster. J. Clean. Prod. 19, 1884–1891. https://doi.org/10.1016/j.jclepro.2011.01.011.

Hansen, T., Coenen, L., 2017. Unpacking resource mobilisation by incumbents for biorefineries: The role of micro- level factors for technological innovation system weaknesses. Tech. Anal. Strat. Manag. 29, 500–513. https://doi.org/10.1080/09537325.2016.1249838.

Hausknost, D., Schriefl, E., Lauk, C., Kalt, G., 2017. A transition to which bioeconomy? An exploration of diverging techno-political choices. Sustainability 9, 1–22. https://doi.org/10.3390/su9040669.

Hedeler, B., Hesser, F., Stern, T., Schwarzbauer, P., 2018. ERIFORE – a Project Dedicated to Foster a Forest-based Bioeconomy, in: Paper & Biorefinery Graz Conference.

Hellsmark, H., Mossberg, J., Patrik, S., 2016. Innovation system strengths and weaknesses in progressing sustainable technology: the case of Swedish biorefinery. J. Clean. Prod. 131, 702–715. https://doi.org/10.1016/j.jclepro.2016.04.109.

Hetemäki, L., Hurmekoski, E., 2014. Forest products and market outlook. In: Future of the European Forest-Based Sector: Structural Changes Towards Bioeconomy, pp. 15–32.

Hetemäki, L., Hänninen, R., Moiseyev, A., 2013. Markets and Market Forces for Pulp and Paper Products. In: Hansen, E., Panwar, R., Vlosky, R. (Eds.), The Global Forest Sector: Changes, Practices, and Prospects. CRC Press, Taylor and Francis Group, Boca Raton, pp. 99–128.

Höher, M., Schwarzbauer, P., Menrad, K., Hedeler, B., Peer, M., Stern, T., 2016. From wood to food: Approaching stakeholder integration in forest-based biorefinery development. J. L. Manag. Food Environ. 67, 165–172. https://doi.org/10.1515/boku-2016-0014.

Hsu, C.-C., Sandford, B.A., 2007. The Delphi technique: making sense of consensus. Pract. Assess. Res. Eval. 12, 1–4.

Huang, H., Ramaswamy, S., Tschirner, U.W., Ramarao, B.V., 2008. A review of separation technologies in current and future biorefineries. Sep. Purif. Technol. 62, 1–21. https://doi.org/10.1016/j.seppur.2007.12.011.

Huber, D.-J., Huber, J., Hersser, F., Höllbacher, E., Stern, T., 2018. Two experts, three opinions: volatile organic compounds' testing methods and regulative systems. Eur. J. Wood Wood Prod. 76, 5–12. https://doi.org/10.1007/s00107-017-1240-5.

Janssen, M., Stuart, P., 2010. Drivers and barriers for implementation of the biorefinery. Pulp Pap. Canada 111, 13–17.

Janssen, M., Chambost, V., Stuart, P.R., 2008. Successful partnerships for the forest biorefinery. Ind. Biotechnol. 4, 352–362. https://doi.org/10.1089/ind.2008.4.352.

Keijsers, E.R.P., Yılmaz, G., van Dam, J.E.G., 2013. The cellulose resource matrix. Carbohydr. Polym. 93, 9–21. https://doi.org/10.1016/J.CARBPOL.2012.08.110.

Kohlöffel, K.M., 2000. Strategisches Management. Carl Hanser Verlag, München.

Kraaijenhagen, C., van Oppen, C., Bocken, N., 2016. Circular Business: Collaborate and Circulate. Circular Collaboration, Amersfoort.

Kurka, S., Menrad, K., 2009. Biorefineries and biobased products from the consumer's point of view. In: 13th ICABR International Conference on Agricultural Biotechnology "The Emerging Bio-Economy." Ravello, pp. 1–33.

Kurttila, M., Pesonen, M., Kangas, J., Kajanus, M., 2000. Utilizing the analytic hierarchy process (AHP) in SWOT analysis — a hybrid method and its application to a forest-certification case. For. Policy Econ. 1, 41–52. https://doi.org/10.1016/S1389-9341(99)00004-0.

Landeta, J., 2006. Current validity of the Delphi method in social sciences. Technol. Forecast. Soc. Change 73, 467–482. https://doi.org/10.1016/j.techfore.2005.09.002.

Langeveld, J.W.A., Dixon, J., Jaworski, J.F., 2010. Development perspectives of the biobased economy: a review. Crop Sci. 50, 142–151. https://doi.org/10.2135/cropsci2009.09.0529.

McCormick, K., Kautto, N., 2013. The bioeconomy in Europe: an overview. Sustain. 5, 2589–2608. https://doi.org/10.3390/su5062589.

McGuire, J.B., Leahy, J.E., Marciano, J.A., Lilieholm, R.J., Teisl, M.F., 2017. Social acceptability of establishing forest-based biorefineries in Maine, United States. Biomass Bioenergy 105, 155–163. https://doi.org/10.1016/j.biombioe.2017.06.015.

Menrad, K., Klein, A., Kurka, S., 2012. Perspective: Jatropha cultivation in southern India: assessing farmers' experiences. Biofuels Bioprod. Biorefin. 6, 246–256. https://doi.org/10.1002/bbb.

Mohan, S.V., Nikhil, G.N., Chiranjeevi, P., Reddy, C.N., Rohit, M.V., Kumar, A.N., 2016. Waste biorefinery models towards sustainable circular bioeconomy: Critical review and future perspectives. Bioresour. Technol. 215, 2–12. https://doi.org/10.1016/j.biortech.2016.03.130.

Näyhä, A., 2012. Towards Bioeconomy: A Three-Phase Delphi Study on Forest Biorefinery Diffusion in Scandinavia and North America. University of Jyväskylä.

Näyhä, A., Pesonen, H., 2012. Diffusion of forest biorefineries in Scandinavia and North America. Technol. Forecast. Soc. Chang. 79, 1111–1120. https://doi.org/10.1016/j.techfore.2012.01.006.

Näyhä, A., Hetemäki, L., Stern, T., 2014. New products outlook. In: Future of the European Forest-Based Sector: Structural Changes Towards Bioeconomy, pp. 43–54.

Näyhä, A., Pelli, P., Hetemäki, L., 2015. Services in the forest-based sector – unexplored futures. J. Manag. Psychol. 11, 4–21. https://doi.org/10.1108/FS-08-2013-0034.

OECD, 2009. The Bioeconomy to 2030: Designing a Policy Agenda. Paris.

Okoli, C., Pawlowski, S.D., 2004. The Delphi method as a research tool: an example, design considerations and applications. Inf. Manag. 42, 15–29. https://doi.org/10.1016/J.IM.2003.11.002.

Oliveira, A., Navia, R., 2017. Zero waste bio-refineries: The example of Brazilian pulp and paper sector. Waste Manag. Res. 35, 1193–1194. https://doi.org/10.1177/0734242X17744399.

Ossadnik, W., Schinke, S., Kaspar, R.H., 2016. Group aggregation techniques for analytic hierarchy process and analytic network process: a comparative analysis. Gr. Decis. Negot. 25, 421–457. https://doi.org/10.1007/s10726-015-9448-4.

Palgan, Y.V., McCormick, K., 2016. Biorefineries in Sweden: perspectives on the opportunities, challenges. Biofuels Bioprod. Biorefin. 10, 523–533. https://doi.org/10.1002/bbb.

Pätäri, S., 2010. Industry- and company-level factors influencing the development of the forest energy business — insights from a Delphi Study. Technol. Forecast. Soc. Chang. 77, 94–109. https://doi.org/10.1016/j.techfore.2009.06.004.

Pätäri, S., Kyläheiko, K., Sandström, J., 2011. Opening up new strategic options in the pulp and paper industry: Case biorefineries. For. Policy Econ. 13, 456–464. https://doi.org/10.1016/j.forpol.2011.06.003.

Pätäri, S., Tuppura, A., Toppinen, A., Korhonen, J., 2016. Global sustainability

megaforces in shaping the future of the European pulp and paper industry towards a bioeconomy. For. Policy Econ. 66, 38–46. https://doi.org/10.1016/j.forpol.2015.10.009.

Peck, P., Bennett, S.J., Bissett-Amess, R., Lenhart, J., Mozaffarian, H., 2012. Perspective: Jatropha cultivation in southern India: assessing farmers' experiences. Biofuels. Bioprod. Bioref. 6, 246–256. https://doi.org/10.1002/bbb.

Priefer, C., Jörissen, J., Frör, O., 2017. Pathways to shape the bioeconomy. Resources 6, 1–23. https://doi.org/10.3390/resources6010010.

Ragauskas, A.J., Williams, C.K., Davison, B.H., Britovsek, G., Cairney, J., Eckert, C.A., Frederick, W.J., Hallett, J.P., Leak, D.J., Liotta, C.L., Mielenz, J.R., Murphy, R., Templer, R., Tschaplinski, T., 2006. The path forward for biofuels and biomaterials. Science 311 (80), 484–489. https://doi.org/10.1126/science.1114736.

Rauch, P., 2006. SWOT analyses and SWOT strategy formulation for forest owner cooperation in Austria. Eur. J. For. Res. https://doi.org/10.1007/s10342-006-0162-2.

Rikkonen, P., Tapio, P., 2009. Future prospects of alternative agro-based bioenergy use in Finland—Constructing scenarios with quantitative and qualitative Delphi data. Technol. Forecast. Soc. Change 76, 978–990. https://doi.org/10.1016/J.TECHFORE.2008.12.001.

Saaty, T.L., 1980. The Analytic Hierarchy Process. McGraw-Hill, New York.

Saaty, T.L., 1986. Axiomatic foundation of the analytic hierarchy process. Manag. Sci. 32, 841–855.

Saaty, T.L., 2008. Decision making with the analytic hierarchy process. Int. J. Serv. Sci. 1, 83. https://doi.org/10.1504/IJSSCI.2008.017590.

Söderholm, P., Lundmark, R., 2009. Biorefineries: implications for market behavior and policy. For. Prod. J. 59, 6–17.

Somerville, J.A., 2007. Critical Factors Affecting the Meaningful Assessment of Student Leaning Outcomes: A Delphi Study of the Opinions of Community College Personnel. Oregon State University.

Stern, T., Heil, G., Ledl, C., Schwarzbauer, P., 2012. Identifying innovation barriers using a Delphi method approach: the case of technical lignin in the wood-based panel industry. Int. Wood Prod. J 3. https://doi.org/10.1179/2042645312Y.0000000015.

Stern, T., Ledl, C., Braun, M., Hesser, F., Schwarzbauer, P., 2015. Biorefineries' impacts on the Austrian forest sector: a system dynamics approach. Technol. Forecast. Soc. Change 91, 311–326. https://doi.org/10.1016/j.techfore.2014.04.001.

Sutterlüty, A., Hesser, F., Schwarzbauer, P., Schuster, K.C., Windsperger, A., Stern, T., 2016. A Delphi approach to understanding varying expert viewpoints in sustainability communication: the case of water footprints of bio based fiber resources. J. Ind. Ecol. 21, 412–422. https://doi.org/10.1111/jiec.12427.

Toppinen, A., Pätäri, S., Tuppura, A., Jantunen, A., 2017. The European pulp and paper industry in transition to a bio-economy: a Delphi study. Futures 88, 1–14. https://doi.org/10.1016/j.futures.2017.02.002.

Van Heiningen, A., 2006. Converting a kraft pulp mill into an integrated forest biorefinery. Pulp Pap. Canada 107, 38–43.

Vandermeulen, V., Van der Steen, M., Stevens, C.V., Van Huylenbroeck, G., 2012. Industry expectations regarding the transition towards a biobased economy. Biofuels Bioprod. Biorefin. 6, 453–464. https://doi.org/10.1002/bbb.1333.